International Journal of Applied Engineering & Technology

IOT BASED SOLAR CHARGE CONTROLLER WITH AUTO ADJUSTABLE PANEL USING IMAGE RECOGNITION

Dinesh Kabra and Dr. Vinesh Agarwal
Phd Research Scolar, Department of Electrical Engineering Sangam University Bhilwara Rajasthan

ABSTRACT
Despite the increasing demand for PV energy, the output from panels and cells does not offer the load with the maximum power it could due to the unpredictable nature of the surrounding environment. Photovoltaic systems rely heavily on maximum power point tracking (MPPT). In this work, the authors provide a novel IoT-based maximum power point tracking (MPPT) solar charge controller (SCC). The proposed circuit system employs IoT-based sensors to upload vital data to the cloud, enabling remote management and tracking. Through the use of the IoT platform, the system can be remotely monitored. The PIC16F73 is the main controller for the projected MPPT-SCC.

Keywords: IoT, Charge Controller, Image Recognition, Solar Charge Controller.

I. INTRODUCTION
The significance of photovoltaic (PV) systems in today's energy landscape has been highlighted by the worldwide shift towards renewable energy sources. Improving the efficiency and dependability of PV systems has emerged as an important focus of study due to the growing dependence on solar energy. There are several obstacles to overcome for PV technology, despite the fact that it has many inherent advantages, including as being abundant and environmentally friendly. Due to the unpredictability of environmental conditions including solar intensity, temperature, and shading, energy output fluctuation is one of the most critical concerns. The efficiency and efficacy of PV panels and cells are reduced because these oscillations prohibit them from functioning at their maximum power point (MPP).

A critical part of PV systems, maximum power point tracking (MPPT) technology was created to deal with these issues. To maximize power output under different situations, maximum power point tracking algorithms continuously change the operating point of PV modules. The efficiency of PV systems is greatly improved by this strategy, which makes solar energy a more practical and dependable power source. The ability to remotely monitor and manage, as well as the system's responsiveness to fast environmental changes, are two areas where conventional MPPT systems fall short.

The combination of MPPT systems with Internet of Things (IoT) technologies provides a potential answer to these restrictions. More complex and responsive control strategies are possible because to the Internet of Things (IoT), which allows for the gathering, transmission, and analysis of real-time data from a variety of sensors. Increased efficiency in PV system monitoring and management is possible with the use of the Internet of Things (IoT).

An innovative maximum power point tracking solar charge controller (MPPT-SCC) based on the internet of things (IoT) is introduced in this study. Solar irradiance, temperature, and voltage are some of the critical characteristics that the suggested system uses sensors based on the Internet of Things to track. By transmitting data to the cloud, these sensors make it possible to remotely monitor and control the PV system. The data can be optimized and adjusted in real-time thanks to the cloud platform's continual oversight. In addition to increasing the PV system's efficiency, this method makes it more reliable and easier to maintain.

In the proposed MPPT-SCC system, the PIC16F73 microcontroller serves as its central component. Data management and MPPT algorithm execution are the responsibilities of this microcontroller, which is attached to the Internet of Things (IoT) sensors. The performance, affordability, and compatibility with other system parts of the PIC16F73 were the deciding factors in its selection. It allows for the efficient and compact implementation of complex MPPT algorithms by providing the required computing power.

The ability to administer and monitor things remotely is a major perk of combining MPPT with the Internet of Things. Manual adjustment and troubleshooting are commonplace in traditional MPPT systems, making them inefficient and time-consuming. By comparison, the MPPT-SCC system that is built on the Internet of Things (IoT) enables remote diagnostics and optimizations, which decreases the requirement for on-site maintenance and speeds up response times for any problems that may emerge. This feature is especially useful for large-scale PV installations and places that are hard to reach or otherwise problematic to manually operate.

Data storage and analysis on the cloud also has other advantages. Operators can do long-term performance evaluations by storing previous data on the cloud. This allows them to spot patterns or trends that might not be obvious at first glance. Future system designs, maintenance plans, and PV system optimization can all benefit from this data.

To summarize, the purpose of this research is to show that PV systems can be significantly more efficient and reliable when they combine MPPT with IoT technologies. To maximize the efficiency of PV systems, the suggested IoT-based MPPT-SCC system makes use of cloud-based analysis, remote management, and real-time data collecting. This new method overcomes the drawbacks of older MPPT systems, opening the door to longer-lasting and more efficient solar power systems.

Proposed Work

[1.] Design & development of an hybrid Solar Charge Controller with remote monitoring and controlling by android application.

[2.] Development of hybrid algorithm for find Maximum Output using Solar Panel.

[3.] Development of hybrid IOT based solar charge controller “Reporting data on server”

[4.] Proposed a Image processing based auto adjustable technique for find maximum output.

II. LITERATURE REVIEW

Dasaratha Sahu et. All (2020) An electric rickshaw (e-Rickshaw) battery charging system that is powered by solar PV is designed and analyzed in this research. The solar module system that is aboard harvests energy from the sun and stores it in a battery bank using an effective maximum power point tracking charge controller. Because of differences in cloud movement and geographical diversity, the irradiance that the solar photovoltaic (PV) system experienced varied. As a result, the efficiency of power extraction is diminished. Thus, an optimal and dependable MPPT setup was necessary for maximal power extraction. Matching the load and supply impedances is the foundation of MPPT's operation. [1]

Ericka Ensimau Sekudan et.All (2017) The purpose of the research is to demonstrate the feasibility of remotely managing a solar array using a cell phone, with the array sending back to the internet the voltage and energy it has absorbed. The purpose of this research is to make managing and gauging the voltage and energy production of solar panels easier. The previous design of solar tracking systems had major flaws. Solar panels that remain in one place cannot precisely follow the sun due to Earth's rotation. [2]

Mayur N Mallya et.All (2021) We use Matlab Simulink to build a solar charge controller that can detect and record the maximum power point as part of our research. The built-in inverter provides a single-phase AC output, so you may use any regular home appliance with it. To find out, we built and compared two algorithms, Incremental Conductance (INC) and Perturb and Observe (P&O), to see which one is better in monitoring the MPP. For optimal monitoring of the maximum power point (MPP) and provision of a regulated DC voltage adequate for the selected pulse width modulation (PWM) inverter in conditions of changing irradiance, a buckboost converter is required. By establishing the link between the key mathematical equations, we can potentially make quantitative predictions about the behavior of the physical system. [3]

N Ragupathi Muthu et.All (2018) Producing electricity using sustainable resources is increasingly considered normal. Solar photovoltaic (PV) technology has come a long way in the last several years, and now it can hold its own against more conventional fossil fuels. In order to create energy, solar photovoltaic panels are linked in both series and parallel at a solar photovoltaic power plant. Significant financial losses might occur even from a short-term decrease in production at a PV power producing facility. The primary alert for faults and creeping adjustments can only be activated when the energy producing stations of a solar PV system are monitored and managed from a central control center. The authorized party could potentially save money by being proactive and fixing issues before they escalate. For this reason, preventative maintenance relies heavily on centralised monitoring and administration. [4]

Pon Vengatesh Ramamurth et.All (2020) A state-of-the-art architecture for energy monitoring and integration of solar power plants has been developed and put into operation, allowing for the maintenance of real-time data on parameters of the plants and the adjustment of the panels' inclination angles to maximize the extraction of PV power. We lay out a systematic way to control and track PV panel attributes using the Internet of Things. For future usage, a reliable archive is established and maintained. By examining the southern region of India and comparing the modular properties of PV panels, we demonstrate that the combinatorial optimization problem of determining the ideal tilt angle throughout the year, season, and month to ensure maximum solar radiation falls on the panels is true. [5]

Mrs. T. Swetha et.All (2022) Within these pages, we argue for the development of a cheap but feature-rich Arduino-based solar battery charger controller. The battery is charged to capacity using the maximum power point tracking (MPPT) method. Working at the PV peak power point allows for a greater power harvest than working at the PV output voltage. The fee controller has several functions including a battery management system, a GSM module for data recording and messaging, and an LCD display. Charge status, external and internal voltages, current, and the option to turn off the battery when thresholds are met are all shown. [6]

Nandar Oo et.All (2016) Despite the many advantages of solar electricity and the apparently endless availability of solar resources, several nations have struggled with successful deployment. In an attempt to standardize the charging process, numerous countries have investigated various methods to the construction of compact, inexpensive charge controllers. In their product descriptions, the majority of high-quality battery manufacturers include voltage control, low-voltage disconnect, and temperature management as essential features. If these guidelines aren't followed, a battery's expected lifespan might be cut in half, regardless of how much you spent on it. [7]

Byou Abdelilah et.All (2018) We may utilize this controller to create new algorithms or conduct comparisons because it was inexpensively constructed utilizing Arduino and still effectively handles tiny DC loads. The experimental data used in this work, such as panel power, battery current, voltage, charge controller status, PWM signal, etc., was provided using the Matlab environment. It is possible to remotely monitor PV installations that are connected to batteries using the data gathering system. [8]

Murizah Kassim et.All (2022) The most innovative aspect of this study is the functioning prototype of an autonomous, flexible, and monitorable solar PV module. Using a data analytics platform, you can keep tabs on voltage LDR, voltage solar, current solar, and power in real time. It merely takes a few seconds to record data and make it readable from a distance. Between 8 and 11 in the morning and 3 and 5 in the afternoon, the static solar panel produces the least amount of electricity. It was demonstrated that the prototype could continually harvest energy from a solar panel. The efficiency boost was 51.82% when compared to a permanently placed solar panel. The most straightforward method to increase production is to align with the sun's schedule, according to scientific evidence. The monitoring system enhances the instructor training curriculum, which is already interesting and easy to understand. [9]

Monika P. Tellawar et.All (2019) Innovative and effective remote monitoring and control systems are needed due to the integration of renewable energy sources into the power distribution network. In this study, we provide a method for remote monitoring of solar panels that is based on the Internet of Things. Analytics may be used to foresee power-generating opportunities, income production, etc., since IoT devices may record performance data and failure data. It also aids in lowering the frequency of servicing calls for solar panels. The Internet of Things (IoT) will provide remote access to solar system controls in previously inaccessible locations. Better energy efficiency, less need for human intervention and supervision, and easier network management are all possible with IoT-based monitoring. [10]

Md. Rokonuzzaman et.All (2016) This research details the design and implementation of an experimental maximum power point tracking charge controller. The suggested system's microcontroller-based control unit is inexpensive, energy-saving, and remarkably efficient. The flexibility and speed of a microcontroller-based solution led to its selection. The proposed system stores data, charges external devices, and displays real-time data, enabling remote monitoring. We have demonstrated and validated experimental results from a 30W prototype system that meets all requirements established by IDCOL, Bangladesh. The average effectiveness of the charge controller, according to the test results, is 91.45%, which is the level needed by the IDCOL Technical Standard Committee (TSC). Also, a lot of renewable power sources can be linked to the grid with the help of an inverter. [11]

Aman Ganesh (2018) In this study, simulations were utilized to demonstrate the detrimental effects of parasitic resistance on the controller's performance. The output voltage is drastically reduced due to the inductor's parasitic resistance, which has a negative impact on the charge controller's efficiency. Because of this, it is essential to use a low-resistance inductor when building the charge controller of an electric vehicle. [12]

Neeraj Kumar Gupta et.All (2018) The proposed stand-alone solar powered system for 4kW loads proved feasible to construct and execute. The computer lssab used by the EN Department's hobby club has been successfully run on a completely solar-powered system. The first testing phase of the project was completed without incident in August of 2018. Multiple voltage and current parameters were accurately collected using an Internet of Things-based energy management system. Long-term operational benefits may be estimated using IoT data once we know the plant's net energy generation. When sufficient data is collected, the ANN might be trained to predict daily energy generation. [13]

T.R. Vignesh et.All (2020) A sustainable mobility gateway is provided by charging electric vehicles (EVs) using solar energy at the workplace. This means that the daytime usage of PV control is possible and the solar power potential of roofs may be investigated. This project examines the PV framework structure and dynamic charging for a solar-powered vitality-fueled EV charging station, in light of the fact that high force happens sometimes in the Netherlands, where the PV control converter can be little in contrast to the PV showcase vitality. Any number of metrological settings throughout the globe may profit from such an approach, as could the power converter and the cluster's master control display. [14]

Ashraf Zaher et.All (2017) This study mapped out the groundwork for a fully automated and smart irrigation system. We were mindful of the enormous amounts of water and energy that are lost in conventional irrigation methods. With the introduction of an automated function, tedious tasks like soil inspection, water pumping needs, and fault detection no longer necessitate a large amount of human work. The suggested ASSIS is practical and simple to implement in horticultural settings such as backyards, rooftops, and expansive fields. Considering the current trend toward using renewable energy, it is encouraging to see solar energy used so extensively. [15]

III. METHODOLOGY

3.1 Solar Charge Controller Algorithm

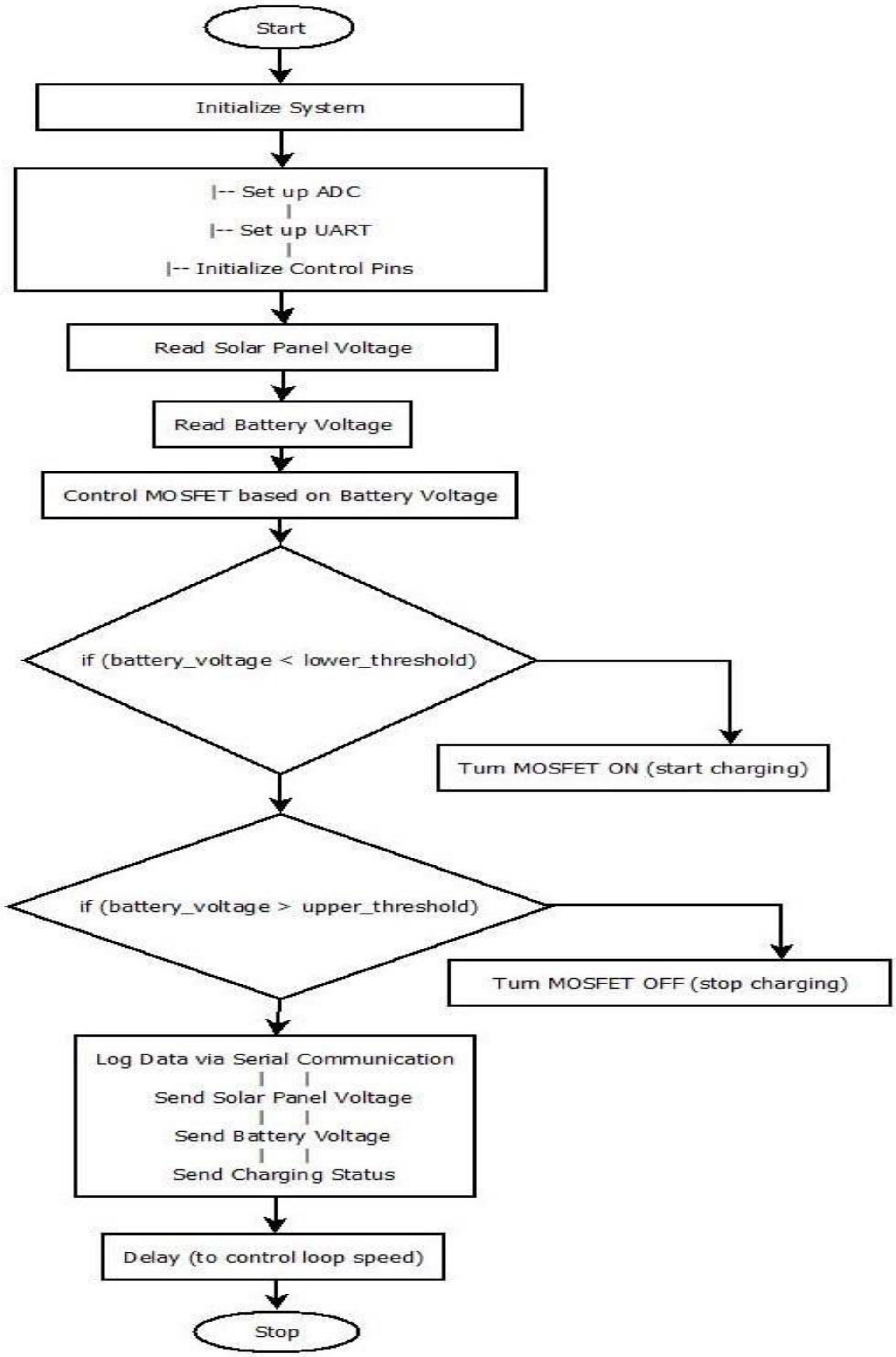

Figure: 3.1 Solar Charge Controller Algorithm Flow Chart

In order to provide safe and effective charging, the solar charge controller hardware is engineered to manage the flow of energy from solar panels to batteries. A solar panel, batteries, and a PIC 16F73 microcontroller are the main parts. There are also a number of electronic components, such as capacitors, resistors, diodes, and transistors.

The charge controller receives the electrical energy that the solar panel produces by converting sunlight into electricity. The metal-oxide semiconductor field-effect transistors regulate the amount of electricity that goes from the solar cells to the battery. In response to changes in the battery voltage, the microcontroller activates or deactivates these MOSFETs. In order to maintain a consistent voltage supply to the battery, capacitors are utilized to dampen voltage variations. To prevent harm from high current, resistors are used to determine operating points and limit current flow.

In order to ensure that energy only travels in the correct direction, diodes are vital in blocking the backflow of current from the battery to the solar panel. The charging process can be better controlled and regulated with the use of transistors, which act as switches and amplifiers inside the circuit. The PIC 16F73 microprocessor acts as the system's central nervous system, coordinating all activities. Through its Analog-to-Digital Converter (ADC) channels, it keeps tabs on the solar panel and battery voltage levels, allowing it to optimize charging in real-time. The microprocessor is also in charge of data logging, which includes providing information about the charging status, voltage of the solar panels, and the battery via UART for analysis and monitoring.

Voltage dividers are used in circuit design to reduce greater voltages to a level that can be read reliably by the microcontroller. To regulate the charging rate and avoid oscillations at high frequencies, gate resistors are positioned between the microcontroller and the MOSFET gates. When switching inductive loads, a flyback diode is used to shield the MOSFET from voltage spikes.

The solar charge controller is designed to prevent the battery from overcharging and undercharging and to maximize the energy harvested from the solar panel. This is achieved by combining these components in an effective manner. An extremely reliable system that can withstand a wide range of environmental conditions is the outcome of meticulously selecting and integrating these hardware components.

The purpose of the microcontroller code that makes up the solar charge controller is to facilitate the safe and efficient charging of batteries by solar radiation. An initialization phase is included in the code at the beginning, where the necessary hardware components are set up. The solar panel and battery voltages can be read by the Analog-to-Digital Converter (ADC), which then converts the analog signals to digital values that the microcontroller can use. The system is able to log and send data through the Universal Asynchronous Receiver-Transmitter (UART), which is initialized for serial connection. The charging process can be controlled by the microcontroller thanks to the fact that the control pins used to drive the MOSFETs are configured as output pins.

The voltages of the solar panel and the batteries are constantly being monitored by the microcontroller in the main loop. In order to ascertain the charging status, the ADC takes readings of these voltages. Whether the microprocessor decides to activate or deactivate the MOSFET is dependent on the voltage reading from the battery. The microcontroller activates the MOSFET, enabling current to flow from the solar panel to the battery, if the battery voltage drops below a specified lower threshold, indicating that the battery requires charging. The microcontroller prevents overcharging by turning off the MOSFET when the battery voltage reaches a certain upper threshold, which indicates that the battery is fully charged.

The system also has a data logging function, where the microcontroller communicates with the serial port to track and analyze the voltage of the solar panels, the battery, and the charging status. In order to monitor system performance and identify problems, this logging is essential. A delay is inserted to regulate the main loop's speed and guarantee steady operation. The system's needed response time will determine the adjustment of this delay. The solar charge controller protects the battery and guarantees optimal charging by following this organized method to managing the energy flow.

3.2 Send Data from NodeMcu to IoT Server for Retrieve Data Using Android App.

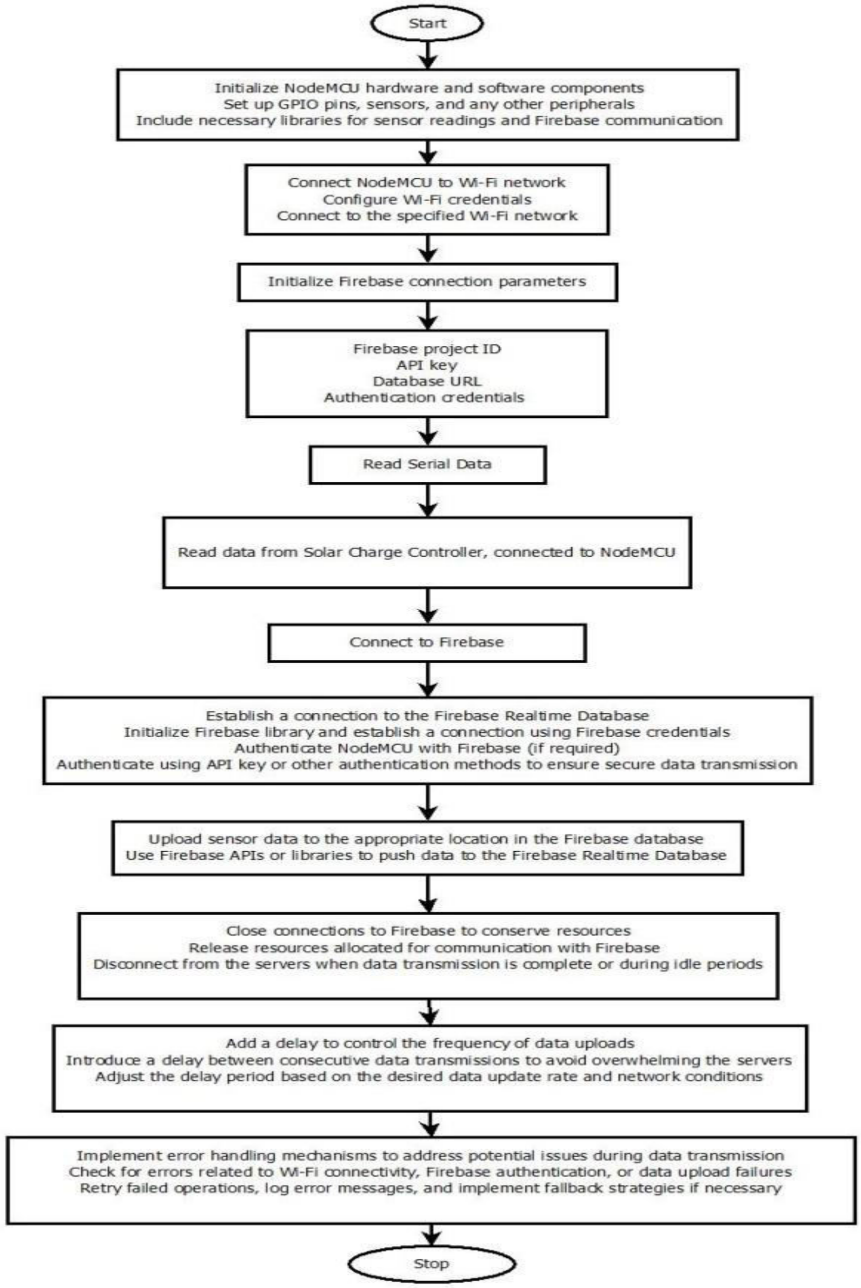

Figure: 3.2 Flow Chart for Send Data to IoT Web Server

Starting with the initialization step, all of the software and hardware components of the NodeMCU are configured, including the GPIO pins, sensors, and communication libraries. After that, the NodeMCU sets up Wi-Fi credentials and joins the local Wi-Fi network. In addition, the Firebase platform's connection parameters, including API keys, project IDs, and database URLs, are set up. The program constantly reads data from the linked solar charge controller within the main loop, which includes a variety of battery and solar charge controller characteristics. The NodeMCU connects to the Firebase Realtime Database after collecting SCC data, and authenticates if needed to ensure secure transmission. Data is prepared for upload to the database by applying

Firebase-specific formats, including metadata like timestamps. Possible transmission faults, such as those involving Wi-Fi connection, Firebase authentication, or failed data uploads, are handled by inbuilt error handling methods. The NodeMCU saves power by removing itself from Firebase after each communication cycle. The main loop keeps running until the program is exited, and a delay is used to manage the update rate between data broadcasts. This all-encompassing method permits real-time data analysis and visualization for different applications by continuously monitoring and transmitting sensor data to the Firebase platform.

3.3 Android Application Flow Chart

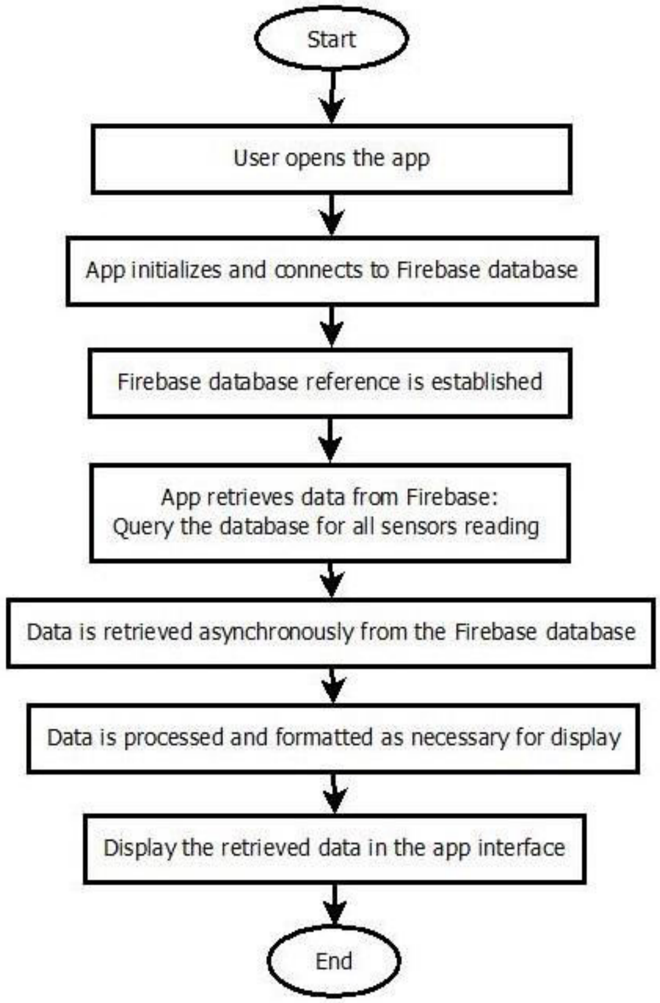

Figure: 3.3 Android Application Flow Chart

Launching the app on the user's device initiates the process, which includes initializing the app and connecting it to the Firebase database. Following the establishment of a secure connection, the application establishes references to various data types housed in Firebase, one of which is the solar charge controller data. Data retrieval problems can be handled by implementing error handling procedures and querying each data type independently. The data is retrieved from Firebase in an asynchronous manner, so the app can keep running seamlessly. After the data has been successfully retrieved, it is processed and formatted so that it may be displayed in the user interface of the program. When the user has finished interacting with the app and gotten the insights they wanted from the data that was shown, the process ends. Users are welcomed by an intuitive interface that links them to data insights in real-time as soon as the program is launched. Users have access to comprehensive information because the application may retrieve a varied variety of environmental characteristics through its connection to the Firebase database. There are strong error-handling procedures in place to deal with any possible interruptions in data retrieval, and every data query is handled with care. The application stays responsive as data is asynchronously retrieved from Firebase, enabling users to engage with the UI without any hiccups. With this function, users may gain a thorough understanding of SCC data, which allows them to make informed decisions and take preemptive measures. In addition, the data that is shown can be interacted with by the users, thanks to the application's user-centric design. In the end, the app is a great resource for people and businesses who want to keep tabs on SCC data and analyze it in real-time.

3.4 Real Time Graphical Visualization Software Flow Chart

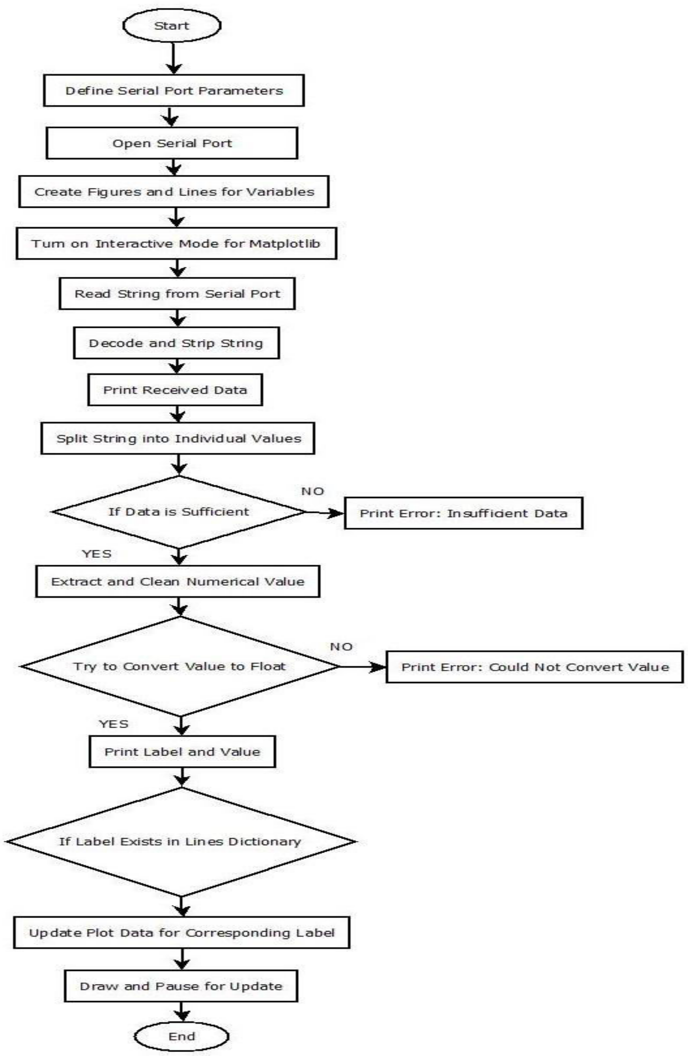

Figure: 3.4 Real Time Graphical Visualization Software Flow Chart

Using a serial connection to read data, process it, and update real-time charts for different variables is the goal of the given Python script. Starting with the port ('COM') and baud rate (9600), the script defines the serial port settings. With these settings, it proceeds to open the serial port. After that, the script prepares the plotting environment by drawing lines and figures for the four relevant variables: temperature, current, voltage, and power. We establish the y-axis limitations and give each variable its own color for the plot. To enable dynamic updating of the graphs, we enabled interactive mode for Matplotlib.

An endless loop is used to continually read data from the serial port, enclosing the essential functionality. After reading data from the serial port, each string is decoded and cleaned of any unnecessary whitespace. Debugging purposes necessitate printing the obtained data. The script then checks if there is enough data received after splitting the data string into separate values. The numerical value is extracted, stripped of any non-numerical characters, and transformed to a float if there is enough data. For the sake of verification, this float value and its label are printed.

The program then verifies if the name is in the lines dictionary that has been previously defined. There is a brief pause and redraw of all plots to reflect the most recent data, and if the label is located, the related plot is updated with the new data point. In order to present the most recent data points, the x-axis bounds are adjusted and the current time and new value are appended to the plot data. To terminate the serial port, clear all plots, and display a message indicating that the port has been closed, the loop must be manually halted using a keyboard operation (e.g., Ctrl+C).

This methodical procedure guarantees the correct plotting and constant updating of real-time data from the serial port, giving a visual depiction of the variables under observation.

3.5 Image Processing Based Auto Adjustable Technique for Find Maximum Output Flow Chart

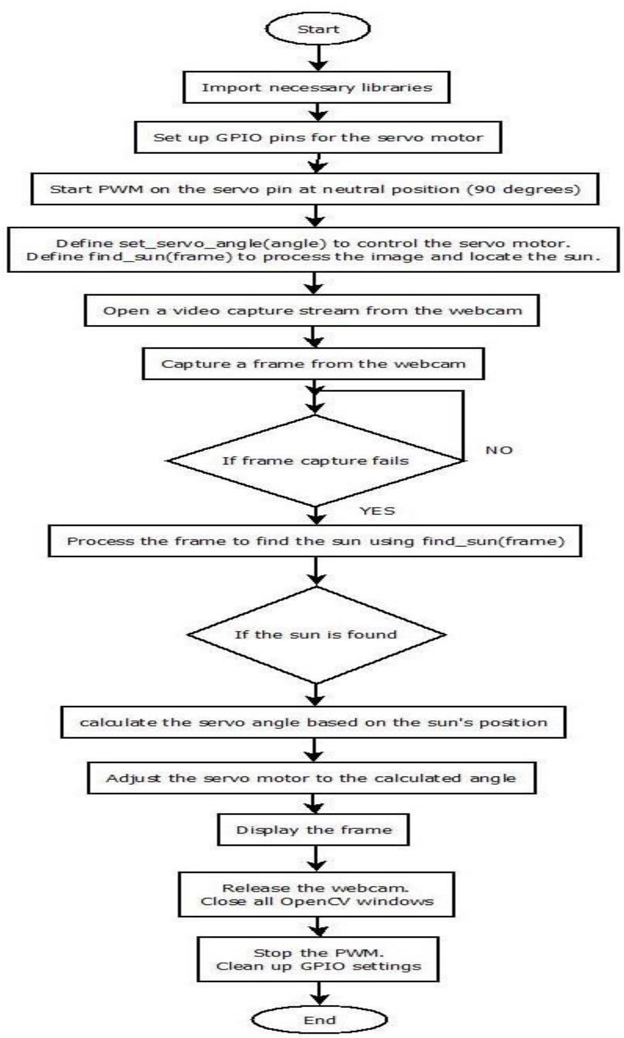

Figure: 3.5 Image Processing Based Auto Adjustable Technique for Find Maximum Output Flow Chart

At the outset, during initialization, you'll import all of the required Python libraries. To process images and manage the webcam feed, you'll need OpenCV (cv2), NumPy for numerical calculations, the RPi.GPIO library to operate the servo motor and interact with the Raspberry Pi GPIO pins, and the time module to handle script delays.

The remaining step is to configure the servo motor's GPIO pins. To use the Broadcom SOC channel (BCM) in GPIO mode, you must set the servo motor's GPIO pin as an output pin. Next, the servo pin is initialized with 50Hz Pulse Width Modulation (PWM), the standard frequency for servos. Turning on the servo motor begins with it in a neutral position, which is 90 degrees, and a duty cycle of 7.5%.

After the initialization, two critical functions are specified. By determining the correct duty cycle based on the angle, the set_servo_angle(angle) function modifies the PWM signal to direct the servo motor to the specified location. It is made sure that the servo has enough time to reach the new location by including a little delay (time.sleep(0.1)). In order to locate the sun in the collected frame, the image processing operation is handled by the find_sun(frame) function. It normalizes the frame to the HSV color space so colors can be more easily detected, specifies the HSV range that can detect yellow (the sun's color in the frame), makes a mask to remove the yellow from the frame, finds contours in the masked image, finds the largest contour (the sun, by assumption), and finds its centroid (cx, cy).

After that, you'll need to open the webcam. The webcam stream is accessed by creating a video capture object with cv2.VideoCapture(0). This item will take pictures all the time to process later. In order to process the video feed in real-time, the script enters the main loop and executes again. The success of capturing a frame from the webcam stream is tested during this loop. If the frame capture doesn't work, the script will go to the cleanup step and the loop will stop.

After a successful frame capture, the find_sun function is used to the data in order to determine the sun's position. To find out if the sun was seen in the frame, a conditional check is used. The loop will proceed to take the following frame even if the sun is not detected. If the sun is found, the appropriate servo angle is determined by mapping the x-coordinate to an interval between zero and one hundred and eighty degrees, using the x-coordinate of the sun's centroid (cx). By passing the computed angle to the set_servo_angle function, the servo motor may be adjusted, bringing the solar panel into alignment with the sun's location as detected.

One way to visually check if the sun tracking procedure is working is to use cv2.imshow('Frame', frame) to display the processed frame in a window. The pressing of the 'q' key triggers yet another conditional check. By pressing the 'q' key, the loop is broken, indicating that the main operation has ended.

The cleanup phase starts once the main loop exits. We free up the webcam resource by releasing the video capture object. Through the use of cv2.destroyAllWindows(), all OpenCV windows that were open throughout the operation are closed. For future operations to run smoothly, we have reset the GPIO settings to their default values and disabled the PWM signal to the servo motor. At last, the script terminates once all resources have been appropriately released and cleaned up. Starting with system startup, this comprehensive exposition moves on to processing video frames, operating the servo motor, and concluding with resource cleanup.

5. RESULTS

5.1 Serial Results

Figure: 5.1 Serial Result 1

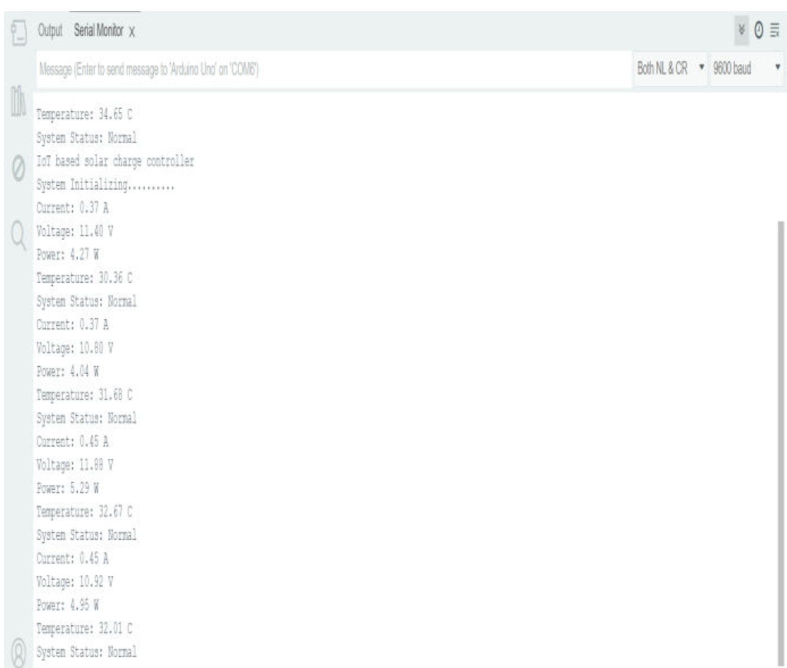

Figure: 5.2 Serial Result 2

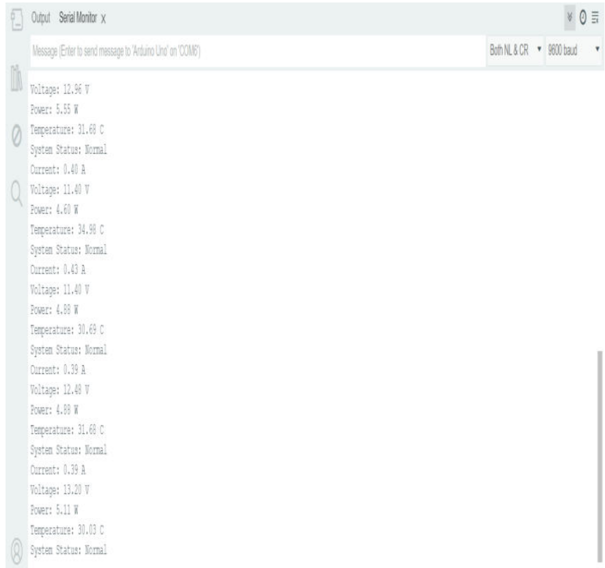

Figure: 5.3 Serial Result 3

An integral part of the system's performance monitoring and analysis is the serial data logging capability of the solar charge controller, which is controlled by the PIC 16F73 microcontroller, as seen in the figures above. An external monitoring system or computer can receive data transmitted by the microcontroller during the initialization phase because the Universal Asynchronous Receiver-Transmitter (UART) is set to permit serial connection. In order to handle the analog signals from the solar panel and battery, the microcontroller's Analog-to-Digital Converter (ADC) channels continuously read them. By analyzing the voltage of the battery, the microcontroller also finds out if the battery is fully charged, requires charging, or is in the process of being charged. The data was captured and sent via UART in the form of a serial data stream. Incorporating a delay into the main loop guarantees constant logging intervals. For diagnostics, early anomaly detection, and real-time insights into the system's performance, periodic logging is crucial. Optimizations to the charging process can be made through analysis of recorded data, leading to overall efficiency gains. The solar charge controller's long-term dependability is enhanced by keeping a record of system performance over time. This allows for predictive maintenance and guarantees that the operating parameters are optimized.

5.2 **Reporting Data on Server**

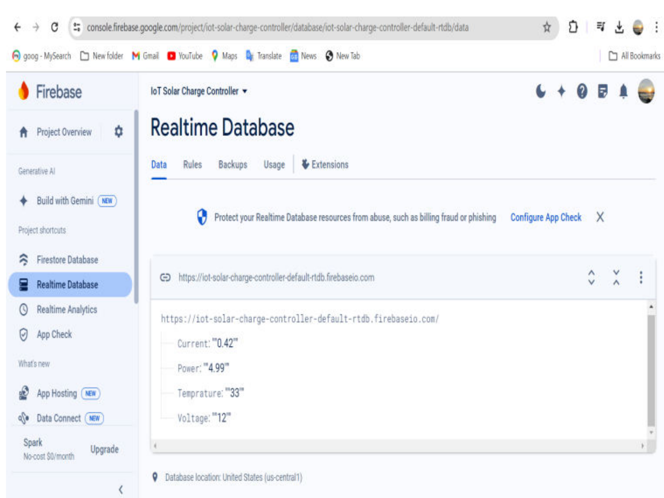

Figure: 5.4 Real Time Database 1

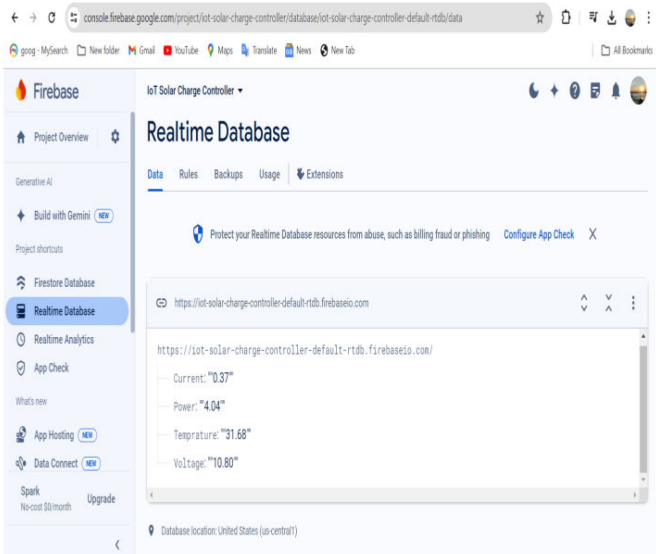

Figure: 5.5 Real Time Database 2

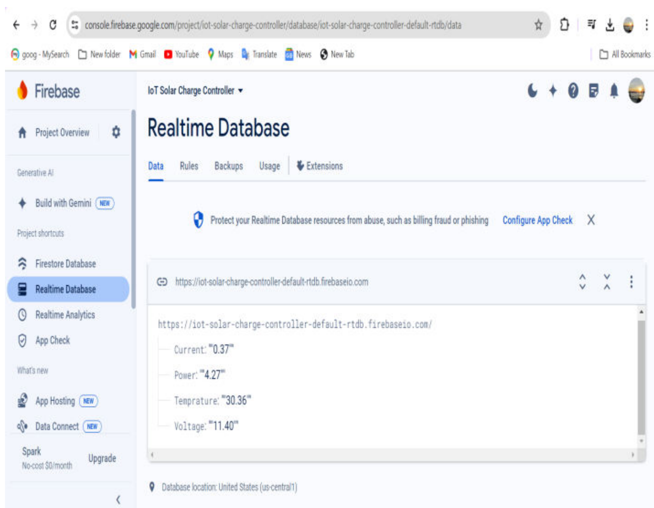

Figure: 5.6 Real Time Database 3

The NodeMCU, acting as an intermediary device, is programmed to receive this serial data and establish a connection with Firebase. Using its built-in Wi-Fi capabilities, the NodeMCU connects to the internet and authenticates with the Firebase Realtime Database. Upon receiving the data from the microcontroller, the NodeMCU parses the serial data, ensuring it is correctly formatted for Firebase. The parsed data, including labeled values like "Voltage: X.XX V", "Current Voltage: Y.YY A", “Power: Z.ZZ W” and "Tempraure", is then uploaded to Firebase.

This setup allows for real-time data updates in the Firebase database, enabling continuous monitoring and analysis of the solar charge controller's performance. The logged data provides real-time insights, aids in early anomaly detection, and is invaluable for diagnostics. By leveraging Firebase, the data is accessible from anywhere, facilitating remote monitoring and management. Analysis of this data can lead to optimizations in the charging process, enhancing overall efficiency. Maintaining a log of system performance over time contributes to the long-term reliability of the solar charge controller, enabling predictive maintenance and ensuring optimal operation parameters.

5.3 Remote Monitoring Using Android Application

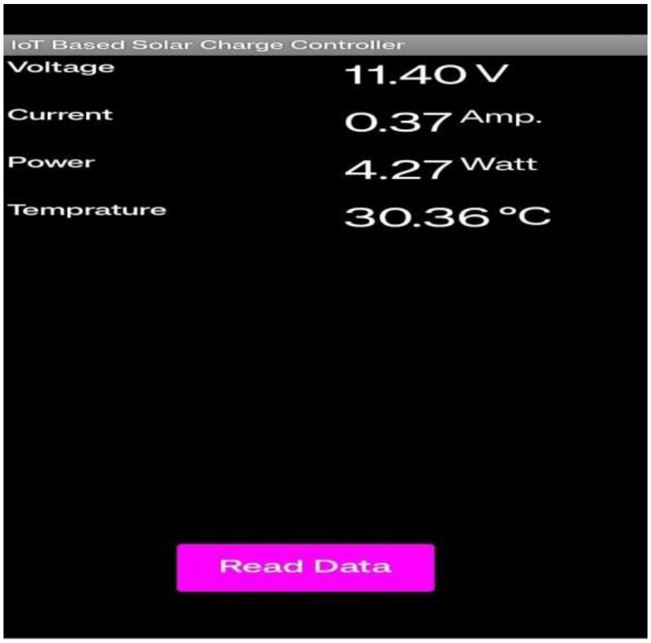

Figure: 5.7 Remote Monitoring Using Android Application 1

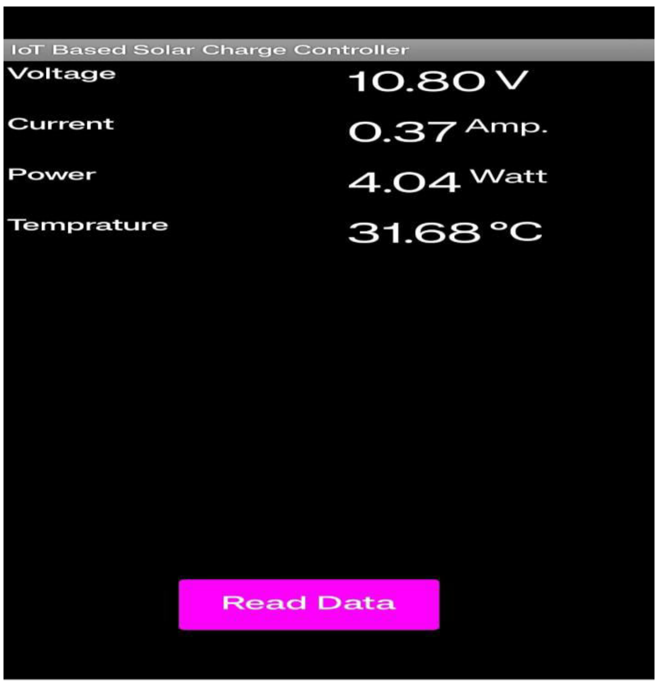

Figure: 5.8 Remote Monitoring Using Android Application 2

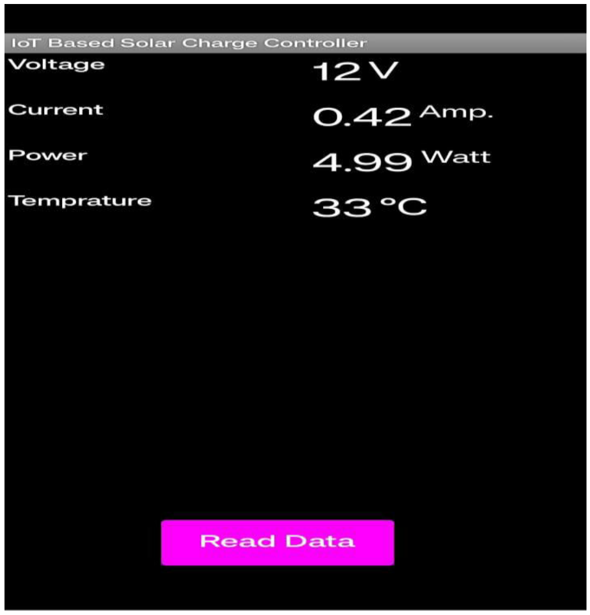

Figure: 5.9 Remote Monitoring Using Android Application 3

The data can be accessed in real-time by proposed Android app after the NodeMCU uploads it to the Firebase Realtime Database. Through the use of Firebase's SDK for Android, the developed Android app establishes a connection to the Firebase database, guaranteeing safe authentication and constant synchronization. The program can immediately incorporate any changes made by the solar charge controller thanks to this real-time data retrieval. The data that was collected is parsed by the app and shown in a straightforward and easy-to-understand numerical format with labels like "Voltage: X.XX V", "Current Voltage: Y.YY A", "Power: Z.ZZ W", and "Temperature: T.TT °C". This is especially helpful for off-grid applications because the data is accessible from anywhere thanks to the interface with Firebase, which lets users remotely monitor and manage their systems. All things considered, this configuration allows for proactive management and crucial insights, which in turn improve the solar charge controller's efficiency and dependability.

3.4 Real Time Monitoring Visualization

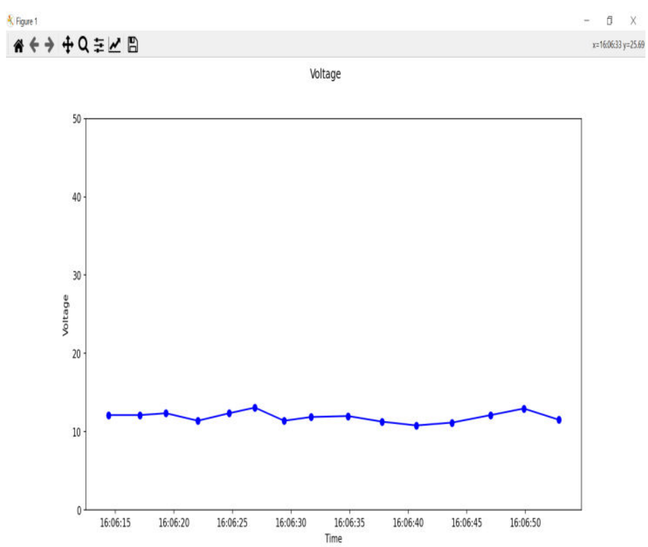

Figure: 5.10 Real Time Voltage Visualization Graph Plot

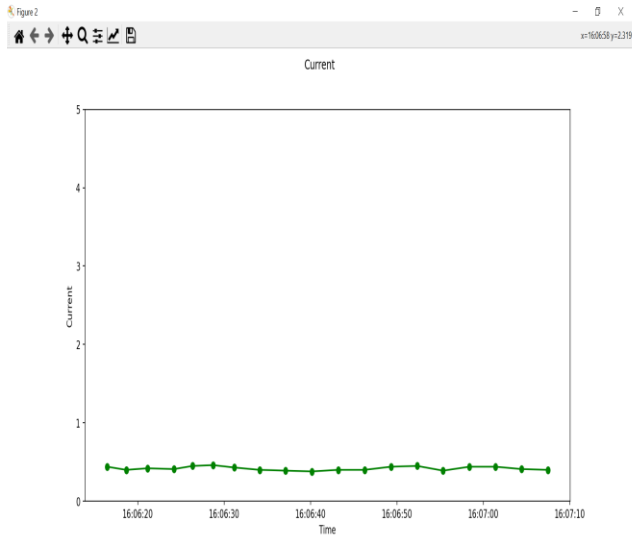

Figure: 5.11 Real Time Current Visualization Graph Plot

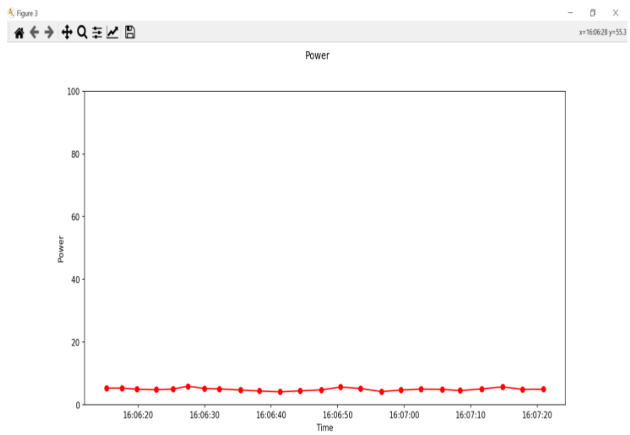

Figure: 5.12 Real Time Power Visualization Graph Plot

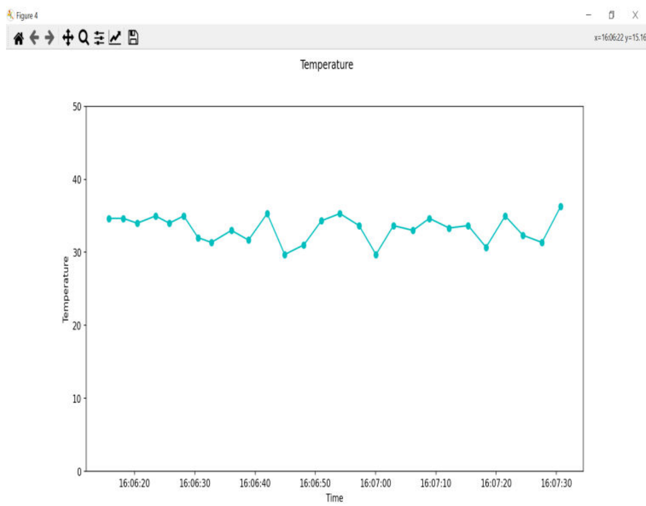

Figure: 5.13 Real Time Temperature Visualization Graph Plot

The practical outcomes of implementing the proposed work are significant for real-time monitoring and analysis of solar charge controller performance parameters graphs in real time as above figures are showing. Users can visually monitor parameters such as voltage, current, power, and temperature in real-time, allowing for immediate identification of any issues or deviations from expected behavior. The continuous plotting of data facilitates the observation of trends over time, which is valuable for performance analysis and optimization. By visualizing these parameters, users can perform more effective diagnostics; for instance, sudden spikes or drops in values can indicate potential problems that require investigation. The use of matplotlib for plotting ensures a clear and user-friendly interface, making it easier to understand complex data streams. Overall, the code offers a comprehensive solution for real-time data acquisition, parsing, and visualization, making it a powerful tool for monitoring and analyzing the performance of systems like a solar charge controller.

3.5 Image Processing Technique for Find Maximum Output Using Solar Array Adjustment

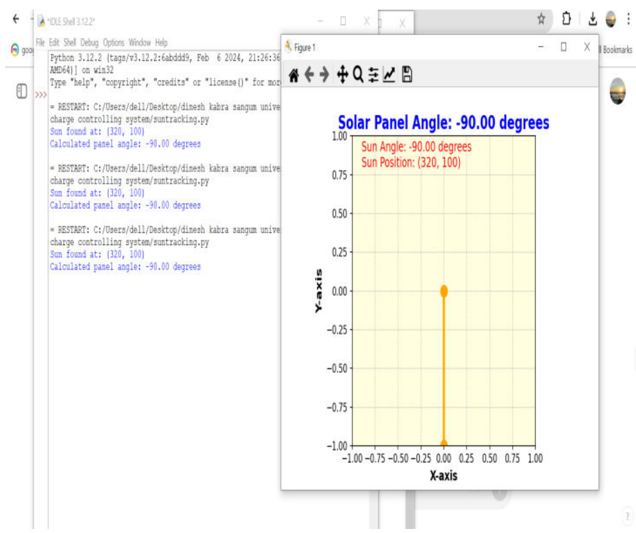

Figure: 5.14 Solar Array Adjustment According to Sun light

The servo motor can turn a full 360 degrees, therefore these coordinates are translated to their appropriate angles. The servo angle is determined by taking the sun's position in the frame as a proportional variable. By modifying the PWM duty cycle, this angle may be controlled, allowing the solar panel to be continuously adjusted to stay in line with the sun and maximizing the amount of energy it captures. Accurate tracking of the sun's location throughout the day is made possible by the continuous detection and adjustment loop, which offers fast feedback. Reliability and user-friendliness are guaranteed by the system's graceful shutdown, which releases resources and stops the servo motor upon exiting the loop. By utilizing image processing techniques, this all-encompassing method improves solar panel performance and offers a practical, user-friendly solution for solar tracking.

VI. CONCLUSION

This research addresses the pressing need for enhanced performance and efficiency in solar photovoltaic (PV) energy systems, particularly in light of the intermittent nature of ambient conditions affecting PV panel output. To overcome this challenge, we developed a novel Internet of Things (IoT)-equipped solar charge controller (SCC). The core objective of our work was to design and implement a hybrid SCC capable of remote monitoring and control through an Android application. Our approach involved the development of a hybrid algorithm tailored for finding the maximum output of solar panels, optimizing their performance under varying conditions. Leveraging IoT technology, our SCC system enables seamless data reporting to a cloud server, facilitating remote monitoring and intervention as needed. Additionally, we proposed an innovative image processing-based auto-adjustment technique, enabling the system to dynamically optimize solar panel positioning for maximum efficiency. Through the integration of these components, our SCC offers a comprehensive solution for maximizing solar energy capture, ensuring efficient power delivery, and providing users with advanced monitoring and control capabilities. This research contributes significantly to advancing renewable energy technologies by addressing key challenges in PV energy utilization and offering practical solutions for improved performance and reliability in solar energy systems.

Comparison of Proposed Work with Base Paper

Parameter	Base paper	Proposed work
Title	Design and Analysis of Solar e-Rickshaw Charging System	IoT Based Solar Charge Controller with Auto Adjustable Panel Using Image Recognition
IoT Enable	No	Yes
Approach	Hardware+ software	Hardware + software + IoT+ android Application
Visualization	Only in software	Software + android application + Real time database
Microcontroller	No	Esp8266+ PIC16F73
Real time data Monitoring Using IoT	No	Yes
Data Transmitting	No	Using Serial Port
Data Visualization Format	Graphs	Graphs + Numeric
Maximum Power Generation Technique	No	Yes
Image Processing Technique	No	Yes
Multi Parameter Analysis	No	Yes (Voltage, Current, Power, Temperature)

Table: 6.1 Comparison of Proposed Work with Base Paper

VII. FUTURE SCOPE

As we look ahead, we can see a plethora of chances to improve solar energy systems even further. Improving MPPT solar charge controllers with more advanced control algorithms is an exciting new direction for research. To improve the system's overall efficiency and adaptability, these algorithms might use cutting-edge methods like AI and machine learning to maximize power generation in real-time, regardless of the changing climatic conditions. The addition of energy storage devices, like batteries, to hybrid SCC systems is also a promising way to increase their functionality. Improving reliability and enabling higher energy self-sufficiency, these systems store extra energy generated during peak sunshine hours. In addition, SCCs could benefit from more Internet of Things integration that would allow for more sophisticated capabilities like predictive maintenance and fault detection in real-time. To achieve this goal, it may be necessary to combine insights from the Internet of Things with predictive modeling methods in order to foresee potential system faults and optimize performance parameters as they occur. Another promising direction for SCC system development is how to integrate them with current power grids and scale them up for bigger installations. Guaranteeing smooth integration of solar energy into the existing infrastructure requires addressing difficulties relating to grid synchronization, power quality management, and grid stability. If we want more people to be able to buy and utilize MPPT SCCs, we need to find ways to cut the cost of the components and simplify the manufacturing process. Finally, in order to comprehend the total sustainability and environmental benefits of solar energy systems, it will be crucial to conduct complete environmental impact evaluations. We can speed up the shift to a renewable energy future and keep solar power technology cutting edge by investigating these potential avenues for future study.

VIII. REFERENCES

[1]. Dasaratha Sahu, P. Srinivasa Rao Nayak "Design and Analysis of Solar e-Rickshaw Charging System" IEEE 2020

[2]. Ericka Ensimau Sekudan, Ahmad Mirza Azhar, Kaiyisah Baiduri Azahar "IoT-Based Solar Energy" International Journal of Recent Technology and Applied Science, 2017.

[3]. Mayur N Mallya, Manasa P, Sameeksh M Shetty, Shamu M, Ms. Soniya Agrawal "SOLAR CHARGE CONTROLLER FOR DOMESTIC APPLICATION" International Journal of Engineering Applied Sciences and Technology, 2021.

[4]. N Ragupathi Muthu, D Devaraj "Development and Performance Analysis of IoT Based Real Time Solar PV Monitoring System" International Journal of Pure and Applied Mathematics, 2018.

[5]. Pon Vengatesh Ramamurthi & Edward Rajan Samuel Nadar "IoT-Based Energy Monitoring and Controlling of an Optimum Inclination Angle of the Solar Panels" IETEJOURNALOFRESEARCH, 2020.

[6]. Mrs. T. Swetha, S. Nikhil, P. Madhuri Lakshmi, T. Mounika, G. Girish kumar, Y. Harsha Vardhan Raj "Solar Based Battery Charging System Through IOT" International Journal of Research in Engineering and Science (IJRES), 2022.

[7]. Nandar Oo, Kyaw Soe Lwin, Hla Myo Tun "A Charge Controller Design For Solar Power System" INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, 2016.

[8]. Byou Abdelilah, Abarkan Mouna, Nacer Kouider M'Sirdi , and Abarkan El Hossain "Solar Charge Controller with a Data Acquisition System Based on Arduino" ICEERE, 2018.

[9]. Murizah Kassim, Fadila Lazim "Adaptive photovoltaic solar module based on internet of things and web-based monitoring system" International Journal of Electrical and Computer Engineering (IJECE), 2022.

[10]. Monika P. Tellawar, Nilesh Chamat "An IOT based Smart Solar Photovoltaic Remote Monitoring System" International Journal of Engineering Research & Technology (IJERT), 2019.

[11]. Md. Rokonuzzaman and Md Hossam-E-Haider "Design and Implementation of Maximum Power Point Tracking Solar Charge Controller" IEEE, 2016.

[12]. Aman Ganesh "Charge Controller for Electric Vehicles" JETIR, 2018.

[13]. Neeraj Kumar Gupta, Aditya Kumar Singh, Ashish D. Thombre and Kirti Pal "Smart Solar Energy Management to Power Computer Lab in Rural Areas" IEEE, 2018.

[14]. T.R. Vignesh, M.Swathisriranjani, R.Sundar, S.Saravanan, T.Thenmozhi "Controller for Charging Electric Vehicles Using Solar Energy" T.R. Vignesh Journal of Engineering Research and Application, 2020.

[15]. Ashraf Zaher, Hidab Hamwi, Aisha Almas, Salma Al-Baitamouni and Mona Al-Bathal "Automated Smart Solar Irrigation System" IEEE, 2017.

[16]. Wallies Thounaojam, V Ebenezer, Avinash Balekundri "Design and Development of Microcontroller Based Solar Charge Controller" International Journal of Emerging Technology and Advanced Engineering, 2014.

[17]. A. I. Edeoghon, J. Chibuzor Okocha, J. S. Ebu, R. E. Ohiocheoya, O. V. Chukwunweike, G. Ebikade, M. Efemena, E. O. Akinlade, Ekwunife Onyeka, Odey Nicholas, Enofe. P "Design and Implementation of an IoT-Based Solar-Powered Inverter Control System" GSJ, 2022.

[18]. P. Selvabharathi, Ashwin V, Clement Vino J and Divakar S "DESIGN OF DC TO DC CONVERTER FOR MPPT CONTROLLER BASED SOLAR PV SYSTEM" International Journal of Electrical Engineering and Technology (IJEET), 2022.

[19]. Osaretin C.A. and Edeko F.O. "DESIGN AND IMPLEMENTATION OF A SOLAR CHARGE CONTROLLER WITH VARIABLE OUTPUT" JOURNAL OF ELECTRICAL AND ELECTRONIC ENGINEERING, 2015.

[20]. Tianxiang Jiang, Ghanim Putrusb, Zhiwei Gao, Matteo Conti, Steve McDonald, Gillian Lacey "Development of a decentral ized smart charge controller for electric vehicles" ELSEVIER, 2014.